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Research Article

Investigation of Thermophysical Properties of Colemanite, Ulexite, and Tincal Reinforced Polyester Composites

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Abstract

In this research, composite material has been obtained by reinforcing colemanite, ulexite, and tincal ore from the boron factory to unsaturated polyester. The effects of these fillers, which are used in different ratios by mass, on the density, Shore D hardness, thermal conductivity coefficient, and thermal stability of the polyester composite have been investigated. According to the results obtained, as the mass ratio of the boron factory components in the mixture raised, the density, hardness, activation energy, and thermal conductivity coefficient of the polyester composite increased. Colemanite increased the density and Shore D hardness of the polyester composite more than other fillers. Besides, tincal ore raised the thermal conductivity coefficient of the polyester composite the least compared to the others. Also, the activation energy values of the polyester composite were ordered from largest to smallest as colemanite, ulexite, and tincal ore according to Coats-Redfern method. The increase in the activation energies of polyester composites is an indication of the raise in thermal stability.

Keywords: Polyester Composite, Density, Shore D hardness, Thermal Conductivity, Activation Energy.

Kolemanit, Üleksit ve Tinkal Takviyeli Polyester Kompozitlerin Termofiziksel Özelliklerinin İncelenmesi

Öz

Bu araştırmada bor fabrikasından çıkan kolemanit, üleksit ve tinkal cevheri doymamış polyestere takviye edilerek kompozit malzeme elde edilmiştir. Kütlece farklı oranlarda kullanılan bu dolguların polyester kompozitin yoğunluğuna, Shore D sertliğine, ısıl iletkenlik katsayısına ve ısıl kararlılığına etkileri araştırılmıştır. Elde edilen sonuçlara göre karışımdaki bor fabrikası bileşenlerinin kütle oranı yükseldikçe polyester kompozitin yoğunluğu, sertliği, aktivasyon enerjisi ve ısıl iletkenlik katsayısı artmıştır. Kolemanit, polyester kompozitin yoğunluğunu ve Shore D sertliğini diğer dolgu maddelerine göre daha fazla arttırmıştır. Ayrıca tinkal cevheri polyester kompozitin ısıl iletkenlik katsayısını diğerlerine göre en az yükseltmiştir. Ayrıca polyester kompozitin aktivasyon enerjisi değerleri Coats-Redfern yöntemine göre kolemanit, üleksit ve tinkal cevheri olarak büyükten küçüğe doğru sıralanmıştır. Polyester kompozitlerin aktivasyon enerjilerindeki artış, termal kararlılıktaki yükselişin bir göstergesidir.

Anahtar Kelimeler: Polyester Kompozit, Yoğunluk, Shore D sertliği, Termal İletkenlik, Aktivasyon Enerjisi.

1. Introduction

Composite materials are designed to combine mechanical, thermal, and electrical properties not found in conventional materials. Due to their unique properties, composite materials are used in many fields, especially in aerospace, automotive, medical, and defense industries [1–8]. Composite materials consist of two main components: fiber materials that provide mechanical properties such as strength and stiffness, and matrix materials that provide load transfer to fibers [9, 10]. Composite materials are divided into three main groups polymer, metal, and ceramic matrix composites [11]. The most widely used composite material today is polymer matrix composites. Thermoset, thermoplastic, and elastomers are used as materials in polymer matrix composites.

One of the most used thermoset resins as matrix material in the production of polymer matrix composites is polyester resins. Polyester resins stand out as matrix materials that can be used in different applications thanks to their high mechanical and electrical strength, excellent adhesion properties, rheological structure, and thermal and chemical stability [12]. The use of man-made synthetic fibers such as carbon, glass, and aramid as fiber materials in composite production has increased various environmental problems because these materials are not biodegradable, expensive, and cannot be recycled [4, 13, 14]. It has been reported that around 7-10 billion tons of urban waste is produced globally every year, and 21 % of this waste consists of industrial wastes [15]. It is thought that the possible usage areas of these wastes will be found and environmental pollution will be prevented [16]. For this reason, the use of waste products and biomaterials in the production of composite materials is being studied intensively by researchers. In the study conducted by Awad and Abdellatif, marble dust wastes were used in the production of composite materials. Mechanical properties of low-density polyethylene composites were determined using 3-point bending, tension, and hardness tests. It has been reported that the mechanical properties of composite materials such as Flexural strength, compression strength, hardness and wear resistance increase with the increase of the marble dust weight percentage [17]. In the study by Vigneswaran et al., the polyester composite was produced by using red mud produced as a waste by-product of Bayer process in alumina production industries, and its mechanical properties were investigated. It has been reported that the hardness, tensile, and impact strength values increase in samples where the red mud content is reinforced up to 20 % [18].

Although there are 230 different boron compounds in nature, some of them (tincal, ulexite, and colemanite) are commercially important compounds. It has been reported that these commercially important boron mineral reserves are mainly found in a few regions of Turkey, USA, Russia, and China [19]. It is used in different fields such as glass, detergent and ceramic industry, energy, agriculture, and medicine. Many by-products that are produced in the production facilities of these minerals are considered waste and create environmental pollution. To minimize the environmental pollution caused by these wastes and to evaluate these products in different production processes, studies have been carried out where they are used in cement and concrete production [20, 21]. It has been determined that boron factory wastes are used in the production of composite materials and that they improve the thermal and mechanical properties of composite materials and have neutron-absorbing properties [22–24].

A study involving polyester composites manufactured using tincal, colemanite, and ulexite reinforcement materials was not found in the literature. For this reason, polyester composite materials were produced by using three different reinforcement materials with different particle sizes. It is aimed to investigate the thermal, physical, and mechanical properties and compare them with pure polyester composite by changing the reinforcement material ratios in the polyester composite material.

2. Material and Method

In this study, unsaturated polyester (UP), cobalt octoate (Co Oc), and methyl ethyl ketone peroxide (MEKP) were purchased from Turkuaz Polyester. Colemanite, ulexite, and tincal ore were procured from Etimaden company in Eskişehir. These fillers taken from the boron factory were ground to -100/200 mesh particle size. In addition, after drying in an oven at 105 °C for 2 hours, it was mixed into unsaturated polyester and homogenized. Then, MEKP and Co Oc catalysts were added to the mixture and the mixture was poured into the molds. After waiting for 24 hours, some thermophysical properties of the polyester composite have been determined [25-30].

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In Table 1, the experimental work plan for colemanite, ulexite, and tincal ores is given separately.

Table 1. Polyester composite preparation plan

UP (g)	MEKP (g)	Co Oc (g)	Fillers (g)
9.8	0.15	0.05	0.0
9.8	0.15	0.05	0.3
9.8	0.15	0.05	0.6
9.8	0.15	0.05	0.9
9.8	0.15	0.05	1.2
9.8	0.15	0.05	1.5

In Figure 1, the production scheme of the polyester composite is expressed. Here, the homogeneity of the filler in the mixture and the addition of catalysts under appropriate conditions are very important.

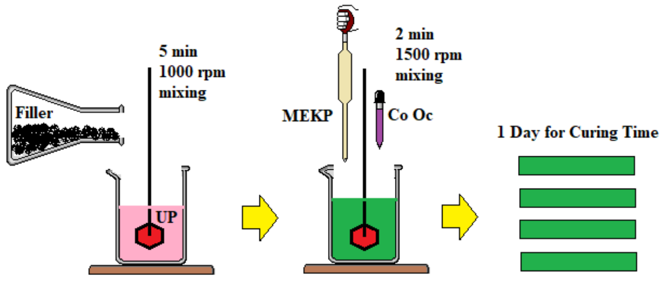

Figure 1. Experimental scheme for the production of composites

3. Results and Discussion

Figure 2 shows the effect of colemanite reinforcement on the density of the polyester composite. It is seen that the density of the polyester composite increases as the composite ratio in the mixture raises. A similar effect of ulexite in Figure 3 and tincal ore in Figure 4 is seen on polyester composite. However, the density increase was determined the lowest in tincal ore and the highest in colemanite.

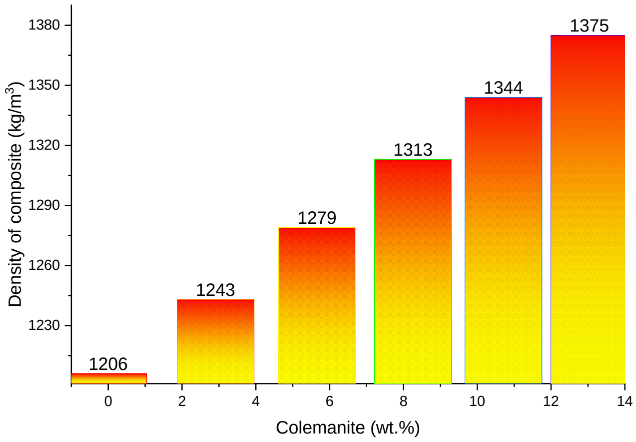

Figure 2. Effect of colemanite reinforcement on the density of polyester composite

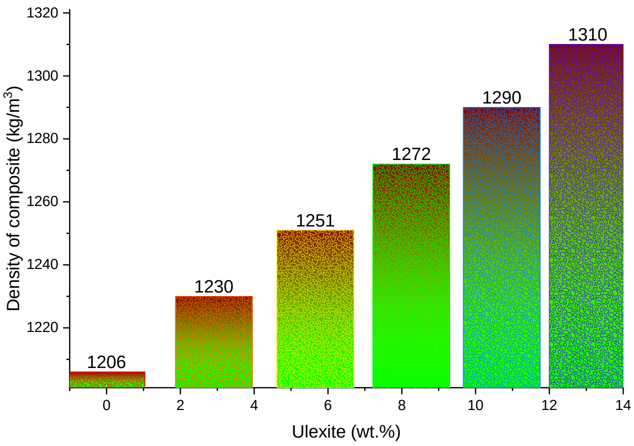

Figure 3. Effect of ulexite reinforcement on the density of the composite

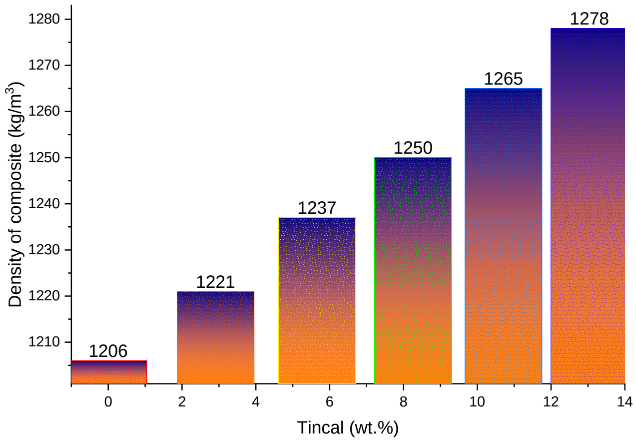

Figure 4. Effect of tincal reinforcement on the density of the composite

In Figure 5, the effect of boron factory components on Shore D hardness of the polyester composite is shown. According to the comparison in the graphic, it has been determined that there was a slight increase in the hardness of the composite. Large to small colemanite, ulexite, and tincal ore increased Shore D hardness of the polyester composite.

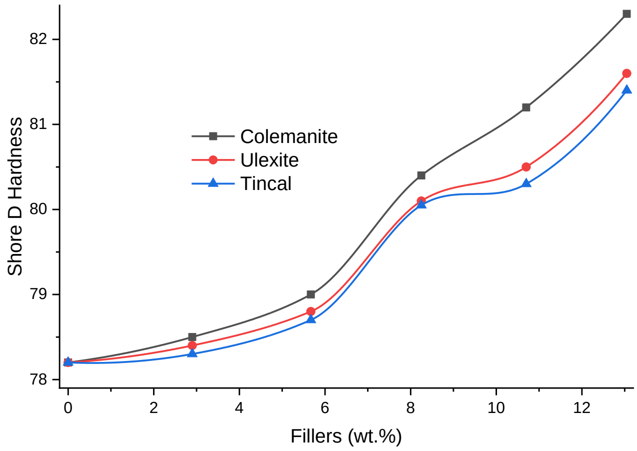

Figure 5. Effect of colemanite, ulexite, and tincal reinforcement on the hardness of the polyester composite

In Figure 6, the thermal conductivity of the composites obtained with the reinforcement of the boron factory components is compared. Colemanite increased the thermal conductivity coefficient of the polyester composite the most and tincal ore the least.

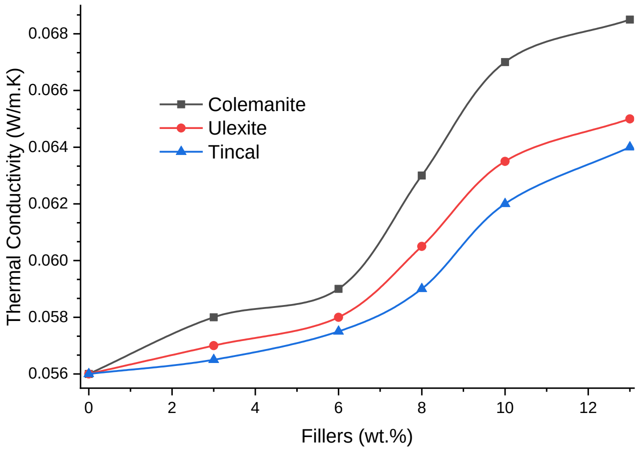

Figure 6. Effect of colemanite, ulexite, and tincal reinforcement on the thermal conductivity of the composite

4. Conclusions and Recommendations

In this study, colemanite, ulexite, and tincal ore were reinforced with unsaturated polyester resin as fillers. These fillers increased the density, Shore D hardness, and thermal conductivity coefficient of the polyester composite. While the effect of colemanite on these increases was maximum, tincal ore had a minimum effect. Besides, the thermal decomposition behavior of polyester composites was examined and activation energies were calculated. Compared to pure polyester, about 8.3 wt.% filler reinforcement increased the activation energy by 12.6 % on average. According to this result, the thermal stability of the polyester composite was increased by the boron factory components [31-33].

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